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SALT CORROSION OF CERAMIC BRICK

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The technological and service reasons for the formation of salting out on brickwork surface and the dynamics of its formation are investigated. The measures needed to prevent and eliminate salt corrosion of brickwork are analyzed.

The study of factors affecting the formation of salting out on the surface of brickwork has identified 16 most important reasons for their origin in the process of construction and maintenance of buildings and structures [1]. The most critical among them is the technological factor related to the chemical composition of argillaceous material and the technology of brick drying and firing.

Potential sources of salting out in brick production may be any batch component: clay, additives, mixing water, as well as the kind of fuel used in firing.

The biggest risk is presented by the alkali metal oxides, i.e., sodium and potassium oxides. Under the effect of moisture they transform into alkalis that can easily participate in exchange reactions with the formation of easily soluble salts, such as Na_2SO_4, Na_2CO_3, etc. The formation of soluble sulfates introduced with mixing water, with fuel introduced into the mixture, or as a result of using sulfur-containing fuel for brick drying and firing is possible even in the presence of 0.5% SO_3 [2].

The high aggressiveness of sodium sulfate solution is due to its volume increasing by 311% as tenardite Na_2SO_4 transforms into mirabilite $Na_2SO_4 \cdot 10H_2O$. This process is the main reason for the emergence of crystallization pressure in the pores of brick and mortar containing solutions of these salts. As the salts react with water, their volume grows in proportion to the quantity of associated crystallization water. Thus, the presence of salting out in the form of Na_2SO_4 on the brick surface not only deteriorates the exterior appearance of the building, but also creates crystallization pressure inside the brick pores leading toits scaling and deterioration of its mechanical parameters.

It should be noted that the intensity of salting out is also related to the type of the pore structure and the size of pores through which the dissolved salts migrate. It is shown in [3] that within the pore size interval of 30 – 400 nm the maximum equilibrium moisture corresponds to a pore size over 300 nm, at the same time, the capillary effect tends to grow as the pore size grows.

Thus, in erecting walls one should use materials that mainly have gel pores of size 30 – 300 nm that impart the highest absorbing capacity to the material and at the same time have the lowest capillary effect. This provides for an increased specific surface area, which extends the diffusion paths of water molecules containing dissolved corrosion products due to forced going around [4].

The migration of dissolved components in brick walls is related to the impact of rain and melting snow, as well as active moisture migration through the enclosing structure onto exterior brickwork surface caused by steam and mass exchange during microclimatic changes inside the building in the spring period, which modifies the direction of water steam migration through the enclosing structures. The walls of the building that have accumulated a substantial amount of moisture during the winter period start drying. In this case the dissolved components of brick wall materials crystallize on the exterior surface of the brick in the form of salting out.

Ceramic brick produced by Izhevsk brick factories was tested for the possibility of the emergence of salting out under a capillary infiltration of distilled water in accordance with the Method for testing argillaceous materials for producing standard and hollow brick, hollow ceramic stone, and drainage pipes (Moscow, 1975) (Fig. 1).

A laboratory sample in the form of a half of a brick was immersed in a low water-filled vessel to a depth of 2 cm with the broken face toward the bottom. For 7 days we maintained a preset level of water in the vessel and intense water evaporation from the sample surface. After 7 days the sample was dried in a drying cabinet at a temperature of 100°C.

To identify salts, the mineralogical analysis of salted-out components taken from the brick surface after capillary infiltration was performed and x-ray phase analysis (DRON-3 diffractometer) was used to determine the mineralogical composition of salts cropping out on the brick surface.

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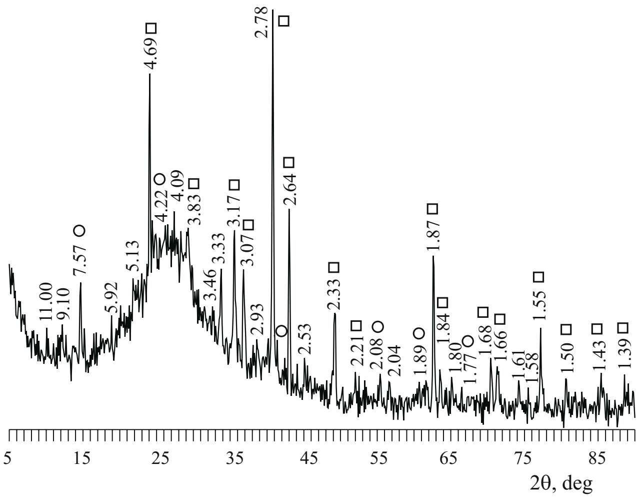

Fig. 1. X-ray diffraction pattern of salting out on brick surface after its testing for capillary infiltration of distilled water: □) Na_2SO_4; ○) $CaSO_4 \cdot 2H_2O$.

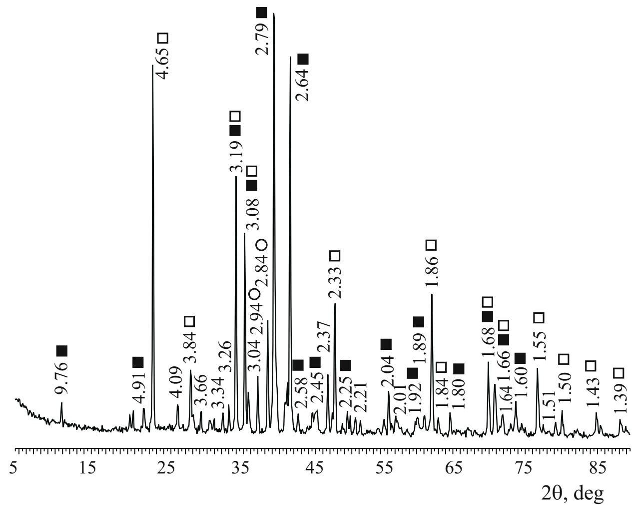

Fig. 2. X-ray diffraction pattern of salting out on the front wall of the circus building being erected in Izhevsk: □) Na_2SO_4; ■) $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$; ○) $Na_2CO_3 \cdot 7H_2O$.

The x-ray phase analysis of salting out on the brick surface after distilled water capillary infiltration demonstrated the presence of sodium sulfate. The salting-out spectra mainly exhibit the reflection lines corresponding to Na_2SO_4 (thenardite): (d_α = 4.64, 3.07, 2.78, 2.64 Å). Furthermore, the spectrum contains calcium sulfate dihydrate (gypsum) (d_α = 7.57, 4.27, 3.07, 2.68, and 2.08 Å). The intense peak on the x-ray spectrum is due to the reflection from the quartz cuvette in which the salt sample was compressed during diffraction analysis.

Thus, thenardite is preset in ceramic brick. The main reason for its formation is related to clays that have an enhanced content of sodium oxide. Clays used for brick production in Izhevsk on the average contain 1.4% sodium oxide. The increased content of sulfur in brick is due to the type of fuel used for brick firing. Natural gas contains a sulfide odorant (diethyl sulfide, dimethyl sulfide) which in combustion produces sulfur oxides reacting with sodium oxide and forming thenardite. The intense saturation of the brick with sodium sulfates starts with the brick drying in a chamber drier using flue gas containing sulfurous anhydride.

The analysis of salts cropping on the surface of brickwork in the buildings considered established the crystallization of two main types of sodium-containing salts: sodium sulfates and sodium carbonates. Sodium sulfates are present on the surface of brick walls saturated with water due to the absence of protective ledges or steel aprons on protruding surfaces.

The reflection lines with maximum intensity in the spectra of such salting out (Fig. 2) correspond to sodium sulfate Na_2SO_4, i.e., thenardite (d_α = 4.65, 3.08, 2.79, and 2.64 Å). Furthermore, rather intense lines are registered that belong to sodium carbonate heptadyrate $Na_2CO_3 \cdot 7H_2O$ (d_α = 2.94, 2.84 Å) and sodium hydrocarbonate $Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O$ (d_α = 9.76, 4.91, 3.08, and 2.64 Å).

All three salts contain sodium that is also present in an excessive amount in Portland cement. The content of sodium oxide in Portland cement is not prescribed by the Construction Rules and Specifications for preparing brickwork mortar. The excess of sodium ions in Portland cement leads to the formation of easily soluble salts, whose solubility is higher by an order of magnitude that that of the most soluble cement stone component: calcium hydroxide $Ca(OH)_2$. The solubility of sodium carbonate at 20°C is 21.8 g/liter against 1.3 g/liter for calcium hydroxide $Ca(OH)_2$, consequently, it is washed out to the brickwork surface in moisture migration. When the ambient humidity increases, sodium carbonate transforms into a steady crystal hydrate form with 10 water molecules; in this case there is a risk of crystallization pressure in the pores of the brickwork due to the initial salt volume growing 1.48 times, which later may lower the strength and cold resistance of the brickwork.

Thus, an additional reason for the formation of salting out on the surface of brickwork in buildings is leaching corrosion related to the excessive quantity of sodium oxide in Portland cement, which should not exceed 0.1% in preparing mortar prone to salting out.

Special cleaning agents are used for effective removal of salt deposits [5]. To decrease the probability of repeated salting out, it is necessary to exclude washing out of salts from solid construction materials, which can be achieved by treating the cleaned surface with a special agent (water-repellent) imparting hydrophobic properties to ceramic brick. A decreasing absorption capacity not only lowers the probability of salting out, but significantly increases the cold resistance of brick.

Hydrophobization is also recommended for exterior surfaces of newly constructed buildings.

The analysis of salts cropping on the brickwork surface in the form of salting out indicates the prevalence of sodium sulfates and carbonates. The reason for the formation of these salts is the presence of sodium sulfates in the brick structure. Sodium carbonates and bicarbonates are washed from the cement mortar by weakly mineralized water, usually in spring period. Both sodium sulfates and carbonates are capable of passing into the crystal hydrate form, in doing so they significantly increase their volumes and destroy the structure of the brickwork materials.

Thus, to prevent deterioration of building exteriors and physicomechanical parameters of brickwork, it is necessary to prevent salt corrosion.

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